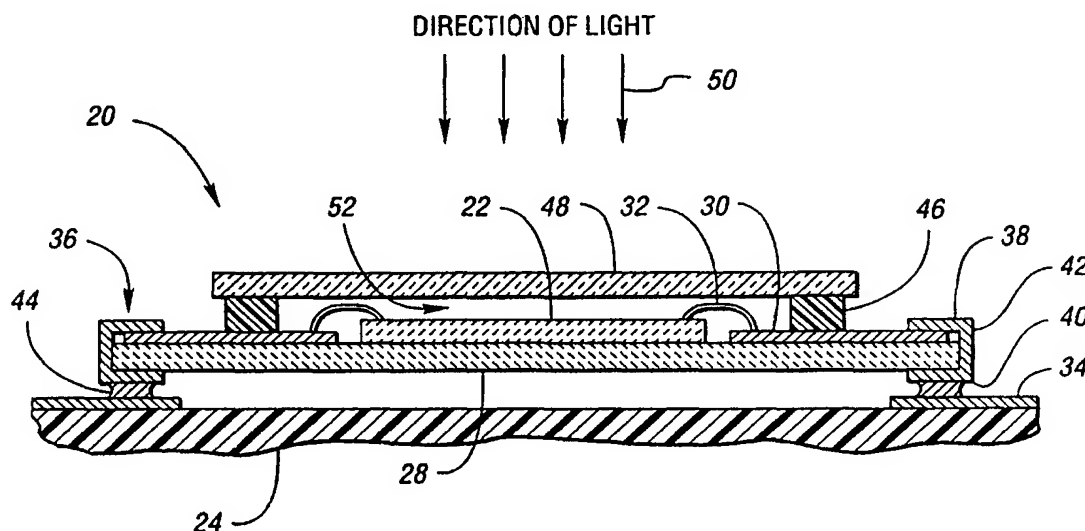




INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification ⁷ : H01L 31/0203	A1	(11) International Publication Number: WO 00/11723 (43) International Publication Date: 2 March 2000 (02.03.00)
<p>(21) International Application Number: PCT/US99/18612</p> <p>(22) International Filing Date: 17 August 1999 (17.08.99)</p> <p>(30) Priority Data: 09/137,909 21 August 1998 (21.08.98) . US</p> <p>(63) Related by Continuation (CON) or Continuation-in-Part (CIP) to Earlier Application US 09/137,909 (CON) Filed on 21 August 1998 (21.08.98)</p> <p>(71) Applicant (for all designated States except US): GENTEX CORPORATION [US/US]; 600 North Centennial, Zeeland, MI 49464 (US).</p> <p>(72) Inventors; and (75) Inventors/Applicants (for US only): BAUER, Fred, T. [US/US]; 236 Dyken Avenue, Holland, MI 49424 (US). STAM, Joseph, Scott [US/US]; 345 South Lakeshore Drive, Holland, MI 49424 (US).</p> <p>(74) Agents: CHUEY, Mark, D. et al.; Brooks & Kushman, 22nd floor, 1000 Town Center, Southfield, MI 48075 (US).</p>		<p>(81) Designated States: AE, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CR, CU, CZ, DE, DK, DM, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZA, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).</p> <p>Published <i>With international search report.</i></p>

(54) Title: PACKAGE FOR AN OPTICAL SENSOR**(57) Abstract**

A package that encapsulates an integrated circuit optical sensor and mounts on a support substrate includes a base substrate constructed of an insulating material. The optical sensor bottom surface is bonded to the base substrate top surface. Conductive strips on the base substrate top surface extend from a region near the optical sensor to an edge of the base substrate top surface. Wires are bonded on one end to a sensor bonding pad for which connection is desired and on the other end to a corresponding conductive strip. A window is bonded to the base substrate top surface in a spaced-apart relationship using seal material extending around the sensor enclosing each wire bond. Various means are provided for connecting each conductive strip to a corresponding trace on the support substrate. An electrochromic variable attenuator may be formed on the window, allowing control over the intensity of light striking the optical sensor.

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PACKAGE FOR AN OPTICAL SENSOR

Technical Field

5 The present invention relates to packaging for integrated circuit optical sensors.

Background Art

10 Integrated circuit optical sensors are increasingly used to provide visual input for control systems as well as in cameras. Many applications place optical sensors in harsh environments, requiring that the sensors be enclosed in a protective package. Presently, commercial optical sensor packages are developed from conventional semiconductor packages incorporating clear plastic or add-on windows to conventional molded or ceramic devices. These packaging assemblies are expensive and difficult to manufacture.

15 An optical sensor may be used in applications exposing the sensor to a range of light intensities beyond the dynamic range of the sensor. As an example, a configuration allowing the sensor to operate at low light levels may cause the sensor to wash out at a high light level. As another example, consider a scene illuminated by florescent lighting, which cycles in intensity with the alternating current supply. A pixel array sensor with a high scan rate will have portions of each frame illuminated by varying levels of light. To avoid this problem, an integration period of at least approximately 30 milliseconds must be used. Since the scan time is generally a multiple of the integration time, a camera set to 30 milliseconds scan period for a bright scene may result in an excessively long scan time for a dim scene. Further,

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particularly if a lens is used to focus light on the sensor, direct exposure to sunlight can generate sufficient heat to damage sensor elements.

Mechanical or electromechanical shutters, when used, are not typically part of the optical sensor package. Electrically attenuated grayscale
5 filters are never part of the commercial sensor device package, if available at all.

What is needed is a package for protecting an optical sensor that is inexpensive and easy to manufacture. The package should be adaptable to include an electronically controlled variable attenuator.

10

Summary Of The Invention

It is an object of the present invention to provide a package for an optical sensor that is inexpensive.

Another object of the present invention is to provide a package for an optical sensor that is easy to manufacture.

15

Still another object of the present invention is to provide a package for an optical sensor that incorporates an electrically controlled variable attenuator.

A further object of the present invention is to provide a method for encapsulating an optical sensor.

20

In carrying out the above objects and other objects and features of the present invention, a package for encapsulating an integrated circuit

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optical sensor is described. The package is mountable on a support substrate. The sensor has a bottom surface and a top surface, the top surface comprising imaging electronics connected to a plurality of sensor bonding pads. The sensor bonding pads provide bonding points for connections off the sensor. The

5 package includes a base substrate with a top surface and a bottom surface. The base substrate is constructed of an insulating material. The base substrate top surface has the optical sensor bottom surface bonded thereon. Conductive strips on the base substrate top surface extend from a region near the optical sensor to an edge of the base substrate top surface. Wires are bonded on one

10 end to a sensor bonding pad for which connection is desired and on the other end to a corresponding conductive strip. A window is bonded to the base substrate top surface in a spaced-apart relationship by a seal material. The window admits light to the optical sensor. A means for connecting each conductive strip to a corresponding trace on the support substrate is also

15 provided. The seal material extends around the sensor enclosing each wire but not enclosing any of the connecting means.

In one embodiment, the means for connecting each conductive strip to the corresponding trace on the support substrate includes a plurality of conductive clips, each clip having a connecting section, an opposing section,

20 and at least one joining section joining the connecting section and the opposing section. The connecting section and the opposing section are separated by a distance less than the thickness of the base substrate. Each clip is placed on the base substrate such that the connecting section is in contact with one conductive strip and the opposing section is in contact with the base substrate bottom

25 surface. In one refinement, the support substrate is a through-hole printed circuit board. Clips include a lead allowing the package to be mounted to the through-hole printed circuit board. In another refinement, the support substrate

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is a flexible circuit and each clip can be attached to the flexible circuit. In yet another refinement, clips can be surface mounted to the support substrate.

In another embodiment, the support substrate defines an opening of sufficient size to accept the window without accepting the entire base substrate. The means for connecting each conductive strip to a corresponding trace on the support substrate has conductive strips formed to provide clipless bonding points to corresponding traces on the support substrate bottom surface. The at least one conductive strip is positioned such that, when the at least one conductive strip is bonded to the corresponding trace, the window is inside the opening.

In still another embodiment, a cavity is formed by the base substrate, the window, and the seal material bonding the window and the base substrate. The cavity is filled with an optically transparent material. This material may be a transparent curable resin.

In yet another embodiment, the window is a first window. The package further includes a first transparent electrode on the top surface of the first window. A second window is bonded to the first window in a spaced-apart relationship by a seal material. The second window bottom surface has a second transparent electrode thereon. The first window, second window, and seal material bonding the second window to the first window form a cavity containing an electrochromic medium of variable transmittance. An electrochromic variable attenuator is formed by the first transparent electrode, the second transparent electrode, and the electrochromic medium, the electrochromic variable attenuator able to regulate the intensity of light admitted to the optical sensor.

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In other embodiments, the window is coated with a film operative to affect the spectrum of light passing through the window and striking the optical sensor. Electro-optic and photochromic filters may be attached to the window. One or more lenses may be attached to the window or
5 the window may be formed to function as one or more lenses.

A method for making the package is also provided. The method includes forming a base substrate from a nonconductive material. Conducting strips are deposited on the base substrate top surface, each strip extending from the region onto which the sensor will be attached to an edge of the base
10 substrate top surface. The bottom surface of the sensor is adhered to the base substrate top surface. Wires are bonded between each sensor bonding pad and a corresponding conducting strip. A window is bonded to the base substrate top surface in a spaced-apart relationship using a seal material. The seal material encloses each wire but does not touch an edge of the base substrate top
15 surface.

In one embodiment, the window is one substrate of an electrochromic variable attenuator.

In another embodiment, wherein the window is a first window, the method further includes depositing a first transparent electrode on the first
20 window top surface. A second window is formed from a nonopaque material, the second window having a bottom surface with a second transparent electrode deposited thereon. The second window is bonded to the first window in a spaced-apart relationship using a seal material. A cavity is formed by the first window, the second window, and the seal material bonding the second window
25 to the first window. At least one opening is formed in the cavity and the cavity is filled with an electrochromic medium. The opening is sealed. Electrical

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connections are attached to the first transparent electrode and the second transparent electrode.

Another package is provided for sensors with bonding pads capable of providing flip chip bonding points. The package includes a base substrate constructed of an insulating material. Conductive strips are on the base substrate bottom surface. The optical sensor top surface is flip chip bonded on the base substrate bottom surface such that each sensor bonding pad is connected to a corresponding conductive strip, each conductive strip extending to the edge of the base substrate. A means for connecting each conductive strip to a corresponding trace on the support substrate is also provided.

In one embodiment, the base substrate is transparent, admitting light to the imaging electronics.

In another embodiment, the base substrate is opaque. A hole in the base substrate permits the optical sensor imaging electronics to receive light. The package further includes a window bonded to the base substrate top surface in a spaced-apart relationship by a seal material. The seal material extends around the hole. The window therefore admitting light to sensor imaging electronics.

In yet another embodiment, a cover is bonded to the base substrate bottom surface by a seal material in a spaced-apart relationship.

In a further embodiment, the optical sensor is coated with a transparent curable resin to provide environmental protection.

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A method for making the package is also provided. The method includes forming a base substrate from a nonconductive material. Conducting strips are deposited on the base substrate bottom surface, each strip extending from the region onto which the sensor will be attached to an edge of the base substrate bottom surface. The sensor top surface is flip chip bonded to the base substrate bottom surface such that each sensor bonding pad is connected to a corresponding conductive strip.

An optical sensor with controlled light attenuation is also provided. The sensor includes an optical sensor assembly having an integrated circuit optical sensor disposed within a package, the package including a package window through which light strikes imaging electronics. A variable attenuator is bonded to the package surface in a spaced-apart relationship using a seal material extending around the package window.

The above objects and other objects, features, and advantages of the present invention are readily apparent from the following detailed description of the best modes for carrying out the invention when taken in connection with the accompanying drawings.

Brief Description Of The Drawings

FIG. 1 is an overhead view of an embodiment of an optical sensor enclosure according to the present invention;

FIG. 2 is a cross-sectional view of the enclosure shown in FIG. 1;

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FIG. 3 is a cross-sectional view of an embodiment of the present invention in which the window is formed as a lens;

FIG. 4 is a cross-sectional view of an embodiment of the present invention using a clipless technology to directly connect conductive strips to traces on the support substrate;

FIG. 5 is a cross-sectional view of an embodiment of the present invention that includes an electrochromic variable attenuator;

FIG. 6 is a graph showing the control characteristics of an electrochromic variable attenuator;

FIG. 7 is a flow diagram showing a process for making an embodiment of the present invention;

FIG. 8 is a cross-sectional view of an embodiment of the present invention using flip chip technology to attach the sensor to the base substrate;

FIG. 9 is a cross-sectional view of an embodiment of the present invention having a transparent base substrate and including a solid state electrochromic variable attenuator;

FIG. 10 is a cross-sectional view of an embodiment of the present invention using a transparent curable resin in place of the back cover; and

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FIG. 11 is a flow diagram showing a process for making an embodiment of the present invention with the sensor flip chip bonded to the base substrate.

Best Modes For Carrying Out The Invention

5 Referring now to FIGS. 1 through 5 and 8 through 10, drawings of embodiments of the present invention are shown. These drawings are not to scale and are provided to show the relationships amongst various elements used to construct the optical sensor package. Further, directional designations such as top and bottom are used for clarity of explanation and are not meant to
10 restrict the present invention to any particular orientation.

Referring now to FIG. 1, an overhead view, and to FIG. 2, a cross-sectional view, an embodiment of the present invention is shown. Enclosure assembly 20 is provided to encapsulate optical sensor 22. Enclosure assembly 20 is designed to be mounted on support substrate 24 which may be,
15 for example, a printed circuit board, flexible circuit, ceramic substrate, or the like.

Optical sensor 22 is an integrated circuit chip. Optical sensor 22 may be, for example, an image sensor including an array of pixel sensors and support electronics. Light sensitive imaging electronics, such as pixel sensors,
20 are constructed on the top side of optical sensor 22. Imaging electronics are connected to sensor bonding pads 26 that provide bonding points for connections off the sensor. Bonding pads 26 have been are not shown in cross-sectional views for clarity.

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In the embodiment shown in FIGS 1 and 2, optical sensor 22 is attached to the top side of base substrate 28 by adhering the bottom side of optical sensor 22 to base substrate 28. Base substrate 28 may be constructed from a nonconducting material such as glass or ceramic.

5 Conductive strips, one of which is indicated by 30, conduct signals and supply voltages between optical sensor 22 and the edge of base substrate 28. Wire 32 connects pads on optical sensor 22 with conductive strips 30. A means for connecting each conductive strip 30 with a corresponding trace 34 on support substrate 24 is provided. Various means are
10 discussed with regards to FIGS. 1 through 4.

 Several means for connecting each conductive strip 30 with a corresponding trace 34 on support substrate 24 use conductive clips, such as C-clips, U-clips, or the like, one of which is shown by 36. Clip 36 has connecting section 38, opposing section 40, and joining section 42 having at
15 least one curved section joining connecting section 38 and opposing section 40 such that connecting section 38 and opposing section 40 are separated by a distance less than the thickness of base substrate 28. Clip 36 is slid onto the edge of base substrate 28 such that connecting section 38 is in contact with conductive strip 26 and opposing section 40 is in contact with base substrate 28
20 bottom surface. In the embodiment shown in FIG. 2, clip 36 is formed to allow enclosure assembly 20 to be reflow soldered as a surface mount part, forming solder joint 44. In an alternate embodiment, a lead is formed as part of clip 36 allowing enclosure assembly 20 to be mounted on a through-hole printed circuit board. Clip 36 with a lead is shown in FIG. 3. Clip 36 can be
25 modified to support various techniques for mounting enclosure assembly 20 to support substrate 24.

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Seal material 46 surrounds optical sensor 22, enclosing each wire 32. Seal material 46 is placed far enough from the edge of base substrate 28 that seal material 46 does not interfere with the assembly of clip 36 onto base substrate 28. Window 48 is bonded to base substrate 28 in a spaced-apart relationship, the spacing distance determined by seal material 46. Window 48 allows light rays 50 to strike imaging electronics on optical sensor 22. Base substrate 28, seal material 46, and window 48 form cavity 52 containing optical sensor 22.

Spacing provided by seal material 46 may be accomplished in a variety of manners. A single polymer collar surrounding optical sensor 22 may be used. Alternately, a plurality of posts may be distributed around optical sensor 22. A sealant may be applied to either the collar or the posts. Preferably, seal material 46 is a combination of a sealant material and a spacing material. The sealant material may be epoxy resin, silicones, rubber cement, low melting temperature glass, certain plastics, paraffin wax, or the like. The spacing material may be small glass beads, nylon monofilament, MYLAR® strips, polystyrene beads, or the like. A preferred seal material 46 is a mixture of glass beads with epoxy resin sealant.

Window 48 may be glass or plastic and may be transparent or nearly transparent (nonopaque). Window 48 may be coated with one or more films to transmit or reject portions of the spectrum of light rays 50. Window 48 may also be manufactured with dyes or fillers within window 48 to allow filtering of light rays 50.

In an embodiment of the present invention, base substrate 28, seal material 46, and window 48 form a hermetically sealed enclosure around optical sensor 22. In another embodiment, cavity 52 is filled with an optically

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transparent curable resin such as epoxy. The resin may be self curing or may be cured by exposure to heat, ultraviolet light, an electron beam, or the like.

Mechanisms for reducing the intensity of light reaching optical sensor 22 may be attached to or formed on window 48. Window 48 may be coated with a photochromic material. Various electro-optic variable attenuators may be placed in front of window 48 such as liquid crystal devices, dipolar suspension devices, electrophoretic devices, suspended particle devices such as those available from Research Frontiers Inc. of Woodbury, New York, electrochromic devices, and the like.

Electrochromic devices contain an electrochromic medium which darkens in response to an applied voltage. The electrochromic medium includes electroactive cathodic and anodic materials that may be independently chosen from at least the categories of solution-phase, surface-confined, and deposition.

In solution-phase media, a material is contained in solution in an ionically conducting electrolyte. The material remains in solution when electrochemically reduced or oxidized. Solution phase electroactive materials may be contained in the continuous solution phase of a free-standing gel as described in U.S. Patent Application Serial Number 08/616,967 entitled "Improved Electrochromic Layer And Devices Comprising Same" by W. L. Tonar et al. which is hereby incorporated by reference.

In surface-confined or solid state media, a material is attached directly to an electrically conducting electrode or confined in close proximity thereto. The material remains attached or confined when electrochemically reduced or oxidized.

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In electrodeposition, a material confined in solution in an ionically conducting electrolyte forms a layer on the electrically conducting electrode when electrochemically reduced or oxidized.

5 A variety of materials that may be used to construct an electrochromic device are described in U.S. Patent Application 08/832,596 entitled "An Improved Electrochromic Medium Capable of Producing A Pre-Selected Color," by K. Baumann et al. which is hereby incorporated by reference.

10 Referring now to FIG. 3, a cross-sectional view of an embodiment of the present invention in which the window is formed as a lens is shown. Window 48 may be constructed to incorporate one or more lenses as shown by window 54. A lens may be formed on the top surface, bottom surface, or both surfaces of window 54. Also, window 54 may be an assembly, allowing multiple lenses of differing material to be placed over
15 optical sensor 22. Further, one or more lenses may be attached to window 48 to create window 54.

FIG. 3 also shows clip 36 with attached pin 56, allowing enclosure assembly 20 to be mounted on through-hole printed circuit board support substrate 24. Clip 36 with attached pin 56 may be of the type known
20 as SOLLOK from Berg Electronics of Etters, Pennsylvania.

Referring now to FIG. 4, a cross-sectional view of an embodiment of the present invention using a clipless technology to directly connect conductive strips to traces on the support substrate is shown. As an alternative to using clip 36, base substrate 28 may be mounted to support
25 substrate 24 using a clipless technology. Support substrate 24 defines an

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opening, shown generally by 58, of sufficient size to accept window 48 without allowing base substrate 28 to pass through. The means for connecting each conductive strip 30 to the corresponding trace 34 on supporting substrate 24 includes forming conductive strip 30 to provide a clipless bonding point to the
5 corresponding trace 34 on support substrate 24. Any suitable clipless technology may be used.

In one embodiment, solder paste 60 is deposited on a wettable region of conductive strip 30. A matching solder wettable terminal footprint is made on trace 34. Base substrate 28 is aligned to support substrate 24 and all
10 solder joints are made simultaneously by reflowing solder paste 60.

Referring now to FIG. 5, a cross-sectional view of an embodiment of the present invention that includes a solution-phase electrochromic variable attenuator is shown. An electrochromic variable attenuator, shown generally by 62, is operative to vary transmittance of light in
15 response to an electrical signal. The operation and construction of an electrochromic device that may be used as electrochromic variable attenuator 62 is described in "Single-Compartment, Self-Erasing, Solution-Phase Electrochromic Devices, Solutions for Use Therein, and Uses Thereof," U.S. Patent Number 4,902,108 to H. J. Byker and hereby incorporated by reference.

20 Electrochromic variable attenuator 62 comprises two non-opaque conductors, referred to as transparent conductors, separated by a reversible variably transmittant solution. First window 48, onto the top surface of which is deposited first transparent electrode 64, forms the first conductor. Second window 66, onto the bottom surface of which is deposited second transparent
25 electrode 68, forms the second conductor. First window 48 and second window 66 are bonded together in a spaced-apart relationship by seal material

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70. First window 48, second window 66, and seal material 70 form cavity 72, which contains electrochromic medium 74.

First window 48 and second window 66 may be constructed of glass or plastic. Window 48,66 may be coated with one or more barrier
5 coatings to protect the plastic from the electrochromic materials, reduce abrasion, and reduce the transmission of contaminants such as moisture and oxygen. Window 48,66 may also be coated to reduce glare, transmit certain spectra, or reject unwanted spectra. The coatings can be transparent, partially
10 transparent, conductive, or partially conductive as required by the function of optical sensor 22. Window 48,66 may be also be filled with a dye to provide desired filtering properties. A thickness for each substrate of between 0.05 cm and 1 cm may be used with a thickness between 0.16 cm and 0.21 cm preferred.

First transparent electrode 64 and second transparent electrode
15 68 may be made of any conductive material that will adhere to the surface of first window 48 and second window 66, that will transmit light, and that will not cause significant degradation of electrochromic medium 74. Possible materials include transparent layers of gold, tin oxide, ruthenium oxide, cadmium stannate, zinc sulfate, and, preferably, indium-doped tin oxide (ITO).
20 First transparent electrode 64 and second transparent electrode 68 will preferably cover the entire surface of first window 48 and second window 66 respectively within cavity 72 and extend outside of cavity 72 into a region on which a connection can be made.

Seal material 70 can be of the same construction as seal material
25 46. In particular, a mixture of small glass beads in an epoxy resin sealant may be used. Further seal materials are described in Byker.

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Electrochromic medium 74 preferably comprises a solvent, at least one cathodic electrochromic compound, and at least one anodic electrochromic compound. An inert current-carrying electrolyte may be added if all cathodic and anodic compounds in their zero-potential equilibrium states are not ionic in solution 74. Preferably, solution 74 may be gelled or thickened with a cross-linked polymer matrix such as IEMA/MMA cross-linked with a dial as described in Tonar et al., serial number 08/616,967. A large number of combinations of solvents, cathodic electrochromic compounds and anodic electrochromic compounds may be used, as described in Byker. One such combination is a solution of 0.05 M 1,1'-dibenzyl-4,4'-bipyridinium difluoroborate and 0.05 M 5,10-dihydro-5,10-dimethylphenazine in propylene carbonate.

Connections to electrodes 64,68 are required. In a preferred embodiment, first transparent electrode 64 extends to an edge of first window 48 and second transparent electrode 68 extends to an edge of second window 66. Clip 76 is attached to each window 48,66 in contact with the respective electrode 64,68. Clip 76 may be of the type described in U.S. Patent Application Serial Number 08/917,643 entitled "An Improved Clip For Use With Transparent Conductive Electrodes In Electrochromic Devices" by W. Tonar et al which is hereby incorporated by reference. Wire 78, attached to clip 76, supplies a control signal to the respective electrode 64,68. In an alternative embodiment, an exposed strip of each electrode extends beyond cavity 72. A conductive strip or wire is attached to the exposed strip and extends beyond the edge of the corresponding window 48,66. This embodiment is further described in Byker.

In an alternative embodiment of the present invention, connections to clips 36,76 are through flexible printed circuits. Clip 36,76 may

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be bonded to a flexible printed circuit using an existing technology such as, for example, chip-on-flex by HEI Inc., which supports both chip and wire as well as flip chip flexible printed circuit connection technologies.

Referring now to FIG. 6, a graph showing the control characteristics of electrochromic variable attenuator 62 is shown. The curve, shown generally as 90, indicates increasing attenuation along the decreasing vertical axis. When the voltage between electrodes 64,68 is low, accomplished by shorting electrodes 64,68 together or by allowing solution 74 to self discharge, the attenuation is low. As depicted by curve section 92, when the control voltage applied across electrodes 64,68 increases from 0 to approximately 0.35 volts, electrochromic variable attenuator 62 becomes slightly attenuating. As control voltage is increased, the attenuation increasing smoothly with increasing control voltage as shown by curve section 94. A maximum attenuation is achieved when the applied control voltage is a little over one volt, as shown in curve section 96. Curve 90 indicates that electrochromic variable attenuator 62 can provide a variable level of attenuation.

The characteristic shown by curve 90 is typical of a fairly wide class of solution phase electrochromic devices, is reasonably reproducible from one unit to another, and is reasonably stable with temperature. However, temperature compensation may optionally be included in using the voltage setting to control the attenuation of electrochromic variable attenuator 62.

By adjusting the chemical composition of solution 74 and the distance through which light must travel through solution 74, defined by the height of cavity 72, the maximum attenuation attainable by electrochromic variable attenuator 62 is adjustable over a wide range. Increasing the

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concentration of solution 74 or height of cavity 72 in general increases the maximum attenuation.

In an alternative embodiment of the present invention, a variable attenuator is bonded to the top of a standard optical sensor. Enclosure
5 assembly 20 is replaced with a commercially available optical sensor such as, for example, the Photobit PB-159. Such sensors have a package window through which imaging electronics can view a scene. A variable attenuator, such as a liquid crystal window, a solid state electrochromic window or, preferably, electrochromic variable attenuator 62, is attached in front of the
10 package window. The variable attenuator is bonded to the standard optical sensor in a spaced-apart relationship by a seal material such as seal material 46.

Referring now to FIG. 7, a flow diagram of a manufacturing process according to the present invention is shown. As will be appreciated by one of ordinary skill in the art, the operations illustrated are not necessarily
15 sequential operations.

Base substrate is formed in block 100. If glass is used, base substrate 28 may be formed from a large sheet of glass having the desired substrate thickness. The glass sheet can be scored or scribed with a set of horizontal and vertical lines using a diamond wheel or the like. The glass sheet
20 is then broken along the scribed lines with spacing between lines determining the surface size of base substrate 28.

Conductive strips are deposited in block 102. Various photolithographic techniques may be used. In one embodiment, a mask is formed on the top surface of base substrate 28 having openings over each area
25 on which conducting strips 26 will be deposited. One or more conducting

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materials or a combination of conducting materials, such as gold, platinum, copper, aluminum or chrome rhodium, is sputtered onto the substrate top surface. The mask is then removed leaving conductive strips 30. In another embodiment, a conducting material is deposited on the top surface of base substrate 28. A mask is formed on the conducting material, the mask covering areas on which each conductive strip 30 will be formed. Base substrate 28 is then exposed to an etchant that dissolves the conducting material not covered by the mask without substantially attacking the material protected by the mask. The mask is removed leaving conductive strips 30. In yet another embodiment, a conductor formed of successive layers of chrome, rhodium, and gold is formed on the surface of base substrate 28. Regions of the conductor are selectively removed with a Nd:YAG laser leaving conductive strips 30. In still other embodiments, conductive strips 30 may be screened and fired or cured.

The optical sensor is adhered to the base substrate in block 104. The bottom surface of optical sensor 22 is bonded to base substrate 28. Techniques for bonding an integrated circuit optical sensor 22 to glass or ceramic base substrate 28 are well known to one of ordinary skill in the art of packaging integrated circuits.

Wires are bonded in block 106. Wire 32 is used to connect sensor bonding pad 26 on optical sensor 22 with a corresponding conductive strip 26. Methods for bonding wires between pads and metal strips are well known in the art of integrated circuit manufacturing.

The window is bonded in block 108. A bead of seal material 46 is made on the top surface of base substrate 28 around the periphery of bonded wires 32. Seal material 46 is placed far enough from the edge of base substrate 28 so as not to interfere with the installation of clips 30 or with clipless

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bonding of base substrate 28 to support substrate 24. Window 48 is pressed onto seal material 46. In a preferred embodiment, seal material 46 includes an epoxy sealant which can be thermal cured or cured by exposure to ultraviolet light. For thermally cured seals, the package is heated prior to bonding window 48 onto base substrate 28 to prevent pressure build up due to expanding gas within cavity 52.

In an embodiment of the present invention, the seal formed between base substrate 28 and window 48 is a hermetic seal. In a preferred embodiment, window 48 can be separated from base substrate 28 by distances ranging between approximately 0.0025 cm and approximately 0.05 cm. In an embodiment, cavity 52 formed by base substrate 28, seal material 46, and window 48 is partially or completely filled with a transparent curable resin.

In an embodiment of the present invention, clips are inserted in block 110. Base substrate 28 extends beyond window 48, exposing portions of conductive strips 30. U- or C-shaped clips 36 are placed on base substrate 28. Each clip 36 has a conductive portion in contact with a corresponding conductive strip 30 and an opposing portion in contact with the bottom surface of base substrate 28. Clip 36 may be soldered to conductive strip 30 to increase adhesion and improve electrical conduction.

In an embodiment of the present invention, window 48 is a substrate of an electro-optic attenuator such as electrochromic variable attenuator 62. The operation of placing the window in block 108 installs the electro-optic attenuator into enclosure assembly 20. Additional constructions that may be used to implement an electrochromic variable attenuator that may be used as an electro-optic attenuator are described in Byker.

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In an alternative embodiment, electrochromic variable attenuator 62 is built onto window 48. First window 48 and second window 66 are formed prior to assembly. If constructed of glass, window 48,66 can be made in a manner similar to that used to make base substrate 28. First transparent electrode 64 and second transparent electrode 68 are formed on first window 48 and second window 66 respectively. Preferably, an optically transparent layer of metal or a metal alloy are deposited onto the substrate. This deposition may occur prior to cutting the substrate pieces or after forming windows 48,66. The sheet resistance of electrodes 64,68 should be less than 100 ohms per square and, preferably, less than 40 ohms per square. The electrodes do not have to cover the entire surface of windows 48,66.

Second window 66 is bonded to first window 48 in a spaced-apart relationship using seal material 70. First window 48 is positioned such that first transparent electrode 64 is on the top surface of first window 48. Second window 66 is positioned such that second electrode 68 is on the bottom surface of second window 66. Bonding first window 48 to second window 66 may be accomplished in the same manner that first window 48 is bonded to base substrate 28 as described in block 108. Also, seal material 70 may have the same construction as described for seal material 46

Two holes are drilled in second window 66. Electrochromic medium 74 is poured into cavity 72 through one hole while air escapes through the other hole. Cavity 72 may be completely filled or may be substantially filled to allow room for expansion. The two holes are plugged, first with a thermoplastic material inert to electrochromic medium 74 then with a sealant such as epoxy.

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Referring now to FIG. 8, a cross-sectional view of an embodiment of the present invention implemented using a flip chip technology is shown. The top of optical sensor 22 is directly flip chip bonded to the bottom of base substrate 28. Base substrate 28 is inverted with respect to the views provided in FIGS. 2 through 5 above in order to consistently show the light direction coming from above. Hence, what was referred to as the top of base substrate 28 in FIGS. 1 through 5 and FIG. 7 becomes the bottom of base substrate 28 in FIGS. 8 through 11. In one embodiment, solder bump 120 joins sensor bonding pad 26, not shown for clarity, with a matching footprint on conductive strip 30.

In the embodiment shown in FIG. 8, base substrate 28 is not transparent. Base substrate 28 includes hole 122. Optical sensor 22 is mounted on base substrate 28 such that imaging electronics on optical sensor 22 are positioned to accept light rays 50 through hole 122.

In an embodiment of the present invention, seal material 124 surrounds hole 122. Window 126 is bonded to base substrate 28 top surface in a spaced-apart relationship using seal material 124. Seal material 124 and window 126 may be constructed in manners described for seal material 46 and window 48 respectively in FIGS. 1 through 7 above. Similarly, window 126 may be used in place of window 48 in all embodiments described with regards to FIGS. 1 through 7 above.

In an another embodiment of the present invention, seal material 128 and cover 130 are included to protect the back side of optical sensor 22. In this embodiment, cover 130 is preferably opaque. Seal material 128 and cover 130 may be constructed as described for seal material 46 and window 48 with regards to FIGS. 1 through 7 above.

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Referring now to FIG. 9, a cross-sectional view of an embodiment of the present invention having a transparent base substrate is shown. Transparent base substrate 140 admits light rays 50 onto imaging electronics on optical sensor 22. This embodiment eliminates the need for hole
5 122, seal material 124, and window 126.

Transparent base substrate 140 may be used as window 48 in the various embodiments and options described with regards to FIGS. 1 through 7 above. For example, electrochromic variable attenuator 62 may be built using transparent base substrate 140 as first window 48 or an electro-optic attenuator,
10 such as electrochromic variable attenuator 62, may be attached to the top of base substrate 140. Also, transparent base substrate 140 may be formed as one or more lens 54, may support one or more lens, may be coated with films, and may incorporate dyes or fillers.

Transparent base substrate 140 may also be used as the substrate
15 of a solid state electrochromic attenuator. This embodiment is shown in FIG. 9. The top surface of transparent base substrate 140 is coated with first transparent electrode 142. Cathodic electrochromic layer 144 is built on first transparent electrode 142. Cathodic electrochromic layer 144 may be comprised of a solid state cathodic material such as, for example, WO_3 .
20 Lithium-containing polymeric electrolyte layer 146 is built on cathodic electrochromic layer 144. Anodic electrochromic layer 148 is built on polymeric electrolyte layer 146. Anodic electrochromic layer 148 may be comprised of oxides of nickel, titanium, cerium, iridium, or the like. Second transparent electrode 150 is built on anodic electrochromic layer 148. First
25 transparent electrode 142 and second transparent electrode 150 may be comprised of gold, tin oxide, ruthenium oxide, cadmium stannate, zinc sulfate, indium-doped tin oxide (ITO), or the like.

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Portions of first transparent electrode 142 may extend from underneath covering layers 144,146,148, 150 to allow for electrical connection. If clips, such as clip 36, are used to connect conductive strips 30 on transparent base substrate 140 to traces 34 on support substrate 24, additional clips may be
5 used to provide control signals to first transparent electrode 142 and second transparent electrode 150. If clipless bonding is used to join transparent base substrate 140 to support substrate 24, wires may be bonded between transparent electrodes 142,150 and corresponding bonding pads on support substrate 24.

Additional constructions for solid state electrochromic
10 attenuators known in the art may also be built on transparent base substrate 140.

Referring now to FIG. 10, a cross-sectional view of an embodiment of the present invention using a transparent curable resin in place of a back cover is shown. In the embodiments described with regards to FIGS.
15 8 and 9, spacer 128 and cover 130 may be replaced or supplemented by a coating of transparent curable resin 154, such as epoxy, around sensor 22. The resin may be self curing or may be cured by exposure to heat, ultraviolet light, an electron beam, or the like.

Any of the embodiments described with regards to FIGS. 8
20 through 10 may use any of the means for connecting each conductive strip 30 to a corresponding trace 34 on the support substrate described with regards to FIGS. 1 through 4 and 7 above. These include clips for direct solder mount or through hole mount to support substrate 24, clipless attachment to support substrate 24, and connection to flexible circuit support substrate 24.

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Referring now to FIG. 11, a flow diagram showing a process for making an embodiment of the present invention with the sensor flip chip bonded to the base substrate is shown. As will be appreciated by one of ordinary skill in the art, the operations illustrated are not necessarily sequential operations.

Base substrate 28,140 is formed in block 160. Base substrate 28,140 may be formed as described with regards to block 100 in FIG. 7 above. For opaque base substrate 28, hole 122 is formed.

Conductive strips are deposited in block 162. Techniques that may be used to form conductive strips 30 on the bottom of base substrate 28 are described with regards to block 102 in FIG. 7 above.

The sensor integrated circuit is flip chip bonded to the base substrate in block 164. The top of optical sensor 22 is bonded to the bottom of base substrate 28 using a flip chip technology such as tape-automated bonding, fluxless solder bumps, isotropic conductive adhesives, anisotropic conductive adhesives, metal bumps, compliant bumps, pressure contacts, and the like. In one embodiment, solder bump 120 is deposited on wettable metal sensor bonding pad 26. A matching solder wettable terminal footprint is made with conductive strip 30 on base substrate 28,140. Optical sensor 22 is aligned to base substrate 28,140 and all solder joints are made simultaneously by reflowing solder bump 120.

In the embodiment wherein substrate 28 is opaque and contains hole 122, seal material 124 is used to bond window 126 to substrate 28. Seal material 124 may be formed as described with regards to forming seal material

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46 in block 108 of FIG. 7. Window 126 may be bonded to base substrate 28 as described with regards to window 48 in block 108 of FIG. 7.

In embodiments including cover 130, seal material 128 and cover 130 may be added as described with regards to seal material 46 and
5 window 48 in block 108 respectively of FIG. 7.

While the best modes for carrying out the invention have been described in detail, other possibilities exist within the spirit and scope of the present invention. For example, additional dies containing support electronics may be enclosed within the package. Those familiar with the art to which this
10 invention relates will recognize various alternative designs and embodiments for practicing the invention as defined by the following claims.

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What is Claimed Is:

1. A package for encapsulating an integrated circuit optical sensor, the package mountable on a support substrate, the sensor having a bottom surface and a top surface, the top surface comprising imaging electronics connected to a plurality of sensor bonding pads, the sensor bonding pads operable to provide bonding points for connections off the sensor, the package comprising:
- 5 a base substrate with a top surface and a bottom surface, the base substrate constructed of an insulating material, the base substrate top surface having the optical sensor bottom surface bonded thereon;
- 10 a plurality of conductive strips upon the base substrate top surface, each conductive strip extending from a region near the optical sensor to an edge of the base substrate top surface;
- a plurality of wires, each wire bonded on one end to a sensor bonding pad for which connection is desired and bonded on the other end to a corresponding conductive strip;
- 15 means for connecting each conductive strip to a corresponding trace on the support substrate; and
- a window bonded to the base substrate top surface in a spaced-apart relationship by a seal material, the seal material extending around the sensor enclosing each wire bond but not enclosing any of the means for connecting each conductive strip to a corresponding trace, the window admitting light to the optical sensor.
- 20
2. A package for encapsulating an integrated circuit optical sensor as in claim 1 wherein the means for connecting each conductive strip to the corresponding trace on the support substrate comprises a plurality of conductive clips, each clip having a connecting section, an opposing section,
- 25

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and at least one joining section joining the connecting section and the opposing section such that the connecting section and the opposing section are separated by a distance less than the thickness of the base substrate, each clip placed on the base substrate such that the connecting section is in contact with one
5 conductive strip and the opposing section is in contact with the base substrate bottom surface.

3. A package for encapsulating an integrated circuit optical sensor as in claim 2 wherein the support substrate is a through-hole printed circuit board and wherein at least one clip further comprises a lead operable to
10 allow the package to be mounted to the through-hole printed circuit board.

4. A package for encapsulating an integrated circuit optical sensor as in claim 2 wherein the support substrate is a flexible circuit and wherein each clip is operable to be attached to the flexible circuit.

5. A package for encapsulating an integrated circuit optical
15 sensor as in claim 2 wherein at least one clip is operable to be surface mounted to the support substrate.

6. A package for encapsulating an integrated circuit optical sensor as in claim 1 wherein the support substrate defines an opening of sufficient size to accept the window without accepting the entire base substrate,
20 the means for connecting each conductive strip to the corresponding trace on the support substrate comprising at least one conductive strip formed to provide a clipless bonding point to a corresponding trace on the support substrate bottom surface, the at least one conductive strip positioned such that, when the at least one conductive strip is bonded to the corresponding trace, the window
25 is inside the opening.

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7. A package for encapsulating an integrated circuit optical sensor as in claim 1 wherein the base substrate is glass.

8. A package for encapsulating an integrated circuit optical sensor as in claim 1 wherein the base substrate is ceramic.

5 9. A package for encapsulating an integrated circuit optical sensor as in claim 1 wherein the window is glass.

10 10. A package for encapsulating an integrated circuit optical sensor as in claim 1 wherein the window is coated with at least one film operative to affect the spectrum of light passing through the window and striking the optical sensor.

11. A package for encapsulating an integrated circuit optical sensor as in claim 1 further comprising an electro-optic filter attached to the window.

15 12. A package for encapsulating an integrated circuit optical sensor as in claim 1 further comprising a photochromic filter attached to the window.

13. A package for encapsulating an integrated circuit optical sensor as in claim 1 further comprising at least one lens attached to the window.

20 14. A package for encapsulating an integrated circuit optical sensor as in claim 1 wherein the window is formed to function as one or more lens.

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15. A package for encapsulating an integrated circuit optical sensor as in claim 1 wherein the seal material comprises:

a sealant; and

5 a plurality of uniformly sized spacer elements mixed with the sealant.

16. A package for encapsulating an integrated circuit optical sensor as in claim 1 wherein a cavity formed by the base substrate, the window, and the seal material bonding the window to the base substrate is filled with an optically transparent material.

10 17. A package for encapsulating an integrated circuit optical sensor as in claim 16 wherein the optically transparent material is a curable resin.

18. A package for encapsulating an integrated circuit optical sensor as in claim 1 wherein the window is a first window, the package further comprising:

15 a first transparent electrode on the top surface of the first window;

20 a second window bonded to the first window in a spaced-apart relationship by a seal material, the second window admitting light to the optical sensor, the second window bottom surface having a second transparent electrode thereon, the first window, the second window, and the seal material bonding the first window and the second window forming a cavity; and

an electrochromic medium of variable transmittance disposed within the cavity;

25 wherein an electrochromic variable attenuator is formed by the first transparent electrode, the second transparent electrode, and the

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electrochromic medium, the electrochromic variable attenuator operable to regulate the intensity of light admitted to the optical sensor.

5 19. A package for encapsulating an integrated circuit optical sensor as in claim 18 further comprising a lens attached to the second window top surface.

 20. A package for encapsulating an integrated circuit optical sensor as in claim 18 wherein at least one of the base substrate, first window, and second window is made of glass.

10 21. A package for encapsulating an integrated circuit optical sensor as in claim 18 wherein at least one of the base substrate, first window, and second window is made of plastic.

 22. A method for encapsulating an integrated circuit optical sensor, the sensor comprising a bottom surface and a top surface, the top surface containing imaging electronics connected to a plurality of sensor bonding pads, the sensor bonding pads operable to provide bonding points for connections off the sensor, the method comprising:

15

 forming a base substrate from a nonconductive material, the base substrate having a top surface and a bottom surface, the base substrate having a region on the top surface onto which the sensor will be attached;

20 depositing a plurality of conducting strips on the base substrate top surface, each strip extending from the region onto which the sensor will be attached to an edge of the base substrate top surface;

 adhering the bottom surface of the sensor to the base substrate top surface;

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bonding a wire between each sensor bonding pad and a corresponding conducting strip; and

bonding a window to the base substrate top surface in a spaced-apart relationship using a seal material, the seal material enclosing each wire but not touching an edge of the base substrate top surface.

23. A method for encapsulating an integrated circuit optical sensor as in claim 22 further comprising placing a clip on the base substrate for each conducting path, each clip extending from one conducting path at the edge of the base substrate top surface to the base substrate bottom surface.

10 24. A method for encapsulating an integrated circuit optical sensor as in claim 22 wherein the base substrate is glass and forming a base substrate comprises:

forming a large sheet of glass;
scoring the glass with vertical and horizontal lines, the spacing
15 between lines defining the size of the base substrate top surface; and
breaking the glass along the scored lines.

25. A method for encapsulating an integrated circuit optical sensor as in claim 22 wherein depositing a plurality of conduction strips comprises depositing successive layers of chrome, rhodium, and gold.

20 26. A method for encapsulating an integrated circuit optical sensor as in claim 22 wherein depositing a plurality of conducting strips on the base substrate top surface comprises:

forming a mask on the base substrate top surface having openings over each area on which each conducting strip will be deposited;

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sputtering a conducting material onto the base substrate top surface; and
removing the mask.

5 27. A method for encapsulating an integrated circuit optical sensor as in claim 22 wherein depositing a plurality of conducting strips on the base substrate top surface comprises:

depositing a conducting material on the base substrate top surface;

10 forming a mask on the deposited conducting material, the mask covering each area on which a conducting strip is desired;

etching away the conducting material exposed by the mask; and
removing the mask.

15 28. A method for encapsulating an integrated circuit optical sensor as in claim 22 wherein the base substrate, the window, and the seal material bonding the window to the base substrate form a cavity, the method further comprising filling the cavity with a transparent curable resin.

29. A method for encapsulating an integrated circuit optical sensor as in claim 22 wherein the window is one substrate of an electrochromic variable attenuator.

20 30. A method for encapsulating an integrated circuit optical sensor as in claim 22 wherein the window is a first window, the method further comprising:

depositing a first transparent electrode on the first window top surface;

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forming a second window from a nonopaque material, the second window having a bottom surface with a second transparent electrode deposited thereon;

5 bonding the second window to the first window in a spaced-apart relationship using a seal material, a cavity thereby formed by the first window, the second window, and the seal material bonding the second window to the first window;

forming at least one opening in the cavity;

10 filling the cavity with an electrochromic medium through the at least one opening;

sealing the at least one opening; and

attaching electrical connections to the first transparent electrode and the second transparent electrode.

31. A package for encapsulating an integrated circuit optical
15 sensor, the package mountable on a support substrate, the sensor comprising a top surface having imaging electronics connected to a plurality of sensor bonding pads, the sensor bonding pads operable to provide flip chip bonding points for connections off the sensor, the package comprising:

20 a base substrate with a top surface and a bottom surface, the base substrate constructed of an insulating material;

a plurality of conductive strips upon the base substrate bottom surface, the optical sensor top surface flip chip bonded on the base substrate bottom surface such that each sensor bonding pad is bonded to a corresponding conductive strip, each conductive strip extending to the edge of the base
25 substrate; and

means for connecting each conductive strip to a corresponding trace on the support substrate.

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32. A package for encapsulating an integrated circuit optical sensor as in claim 31 wherein the base substrate is transparent, the base substrate admitting light to the imaging electronics.

5 33. A package for encapsulating an integrated circuit optical sensor as in claim 32 wherein the base substrate is glass.

34. A package for encapsulating an integrated circuit optical sensor as in claim 32 wherein the base substrate is coated with at least one film operative to affect the spectrum of light passing through the base substrate and striking the optical sensor.

10 35. A package for encapsulating an integrated circuit optical sensor as in claim 32 further comprising an electro-optic filter attached to the base substrate top surface.

15 36. A package for encapsulating an integrated circuit optical sensor as in claim 32 further comprising a photochromic filter attached to the base substrate top surface.

37. A package for encapsulating an integrated circuit optical sensor as in claim 32 further comprising at least one lens attached to the base substrate.

20 38. A package for encapsulating an integrated circuit optical sensor as in claim 32 wherein the base substrate is formed to function as one or more lens.

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39. A package for encapsulating an integrated circuit optical sensor as in claim 32 the package further comprising:

a first transparent electrode on the base substrate top surface;

a window bonded to the base substrate in a spaced-apart

5 relationship by a seal material, the window admitting light to the optical sensor, the window bottom surface having a second transparent electrode thereon, the base substrate, the window, and the seal material bonding the window to the base substrate forming a cavity; and

10 an electrochromic medium of variable transmittance disposed within the cavity;

wherein an electrochromic variable attenuator is formed by the first transparent electrode, the second transparent electrode, and the electrochromic medium, the electrochromic variable attenuator operable to regulate the intensity of light admitted to the optical sensor.

15 40. A package for encapsulating an integrated circuit optical sensor as in claim 39 further comprising a lens attached to the window top surface.

41. A package for encapsulating an integrated circuit optical sensor as in claim 32 further comprising:

20 a first transparent electrode on base substrate top surface;

a cathodic electrochromic layer on the first transparent electrode;

a polymeric electrolyte layer on the cathodic electrochromic layer;

25 an anodic electrochromic layer on the polymeric electrolyte layer; and

a second transparent electrode on the anodic electrochromic layer.

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42. A package for encapsulating an integrated circuit optical sensor as in claim 31 wherein the base substrate is opaque, the base substrate forming a hole through which the optical sensor imaging electronics receive light, the package further comprising a window bonded to the base substrate top surface in a spaced-apart relationship by a seal material, the seal material
5 extending around the hole, the window admitting light to the imaging electronics.

43. A package for encapsulating an integrated circuit optical sensor as in claim 42 wherein the seal material comprises:
10 a sealant; and
a plurality of uniformly sized spacer elements mixed with the sealant.

44. A package for encapsulating an integrated circuit optical sensor as in claim 42 wherein the window is coated with at least one film
15 operative to affect the spectrum of light passing through the window and striking the optical sensor.

45. A package for encapsulating an integrated circuit optical sensor as in claim 42 further comprising an electro-optic filter attached to the window top surface.

20 46. A package for encapsulating an integrated circuit optical sensor as in claim 42 further comprising a photochromic filter attached to the window top surface.

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47. A package for encapsulating an integrated circuit optical sensor as in claim 42 further comprising at least one lens attached to the window.

5 48. A package for encapsulating an integrated circuit optical sensor as in claim 42 wherein the window is formed to function as one or more lens.

49. A package for encapsulating an integrated circuit optical sensor as in claim 42 wherein the window is a first window, the package further comprising:

10 a first transparent electrode on the first window top surface;
a second window bonded to the first window top surface in a spaced-apart relationship by a seal material, the second window admitting light to the optical sensor, the second window bottom surface having a second transparent electrode thereon, the first window, the second window, and the
15 seal material bonding the second window to the first window forming a cavity;
and

an electrochromic medium of variable transmittance disposed within the cavity;

20 wherein an electrochromic variable attenuator is formed by the first transparent electrode, the second transparent electrode, and the electrochromic medium, the electrochromic variable attenuator operable to regulate the intensity of light admitted to the optical sensor.

50. A package for encapsulating an integrated circuit optical sensor as in claim 49 further comprising a lens attached to the second window
25 top surface.

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51. A package for encapsulating an integrated circuit optical sensor as in claim 31 wherein the means for connecting each conductive strip to the corresponding trace on the support substrate comprises a plurality of conductive clips, each clip having a connecting section, an opposing section,
5 and at least one joining section joining the connecting section and the opposing section such that the connecting section and the opposing section are separated by a distance less than the thickness of the base substrate, each clip placed on the base substrate such that the connecting section is in contact with one conductive strip and the opposing section is in contact with the base substrate
10 bottom surface.

52. A package for encapsulating an integrated circuit optical sensor as in claim 51 wherein the support substrate is a through-hole printed circuit board and wherein at least one clip further comprises a lead operable to allow the package to be mounted to the through-hole printed circuit board.

15 53. A package for encapsulating an integrated circuit optical sensor as in claim 51 wherein the support substrate is a flexible circuit and wherein each clip is operable to be attached to the flexible circuit.

54. A package for encapsulating an integrated circuit optical sensor as in claim 51 wherein at least one clip is operable to be surface
20 mounted to the support substrate.

55. A package for encapsulating an integrated circuit optical sensor as in claim 31 wherein the support substrate defines an opening of sufficient size to accept the window without accepting the entire base substrate, the means for connecting each conductive strip to the corresponding trace on
25 the support substrate comprising at least one conductive strip formed to provide

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a clipless bonding point to the corresponding trace on the support substrate bottom surface, the at least one conductive strip positioned such that, when the at least one conductive strip is bonded to the corresponding trace, the window is inside the opening.

5 56. A package for encapsulating an integrated circuit optical sensor as in claim 31 further comprising a cover bonded to the base substrate bottom surface in a spaced-apart relationship by a seal material, the seal material extending around the sensor.

10 57. A package for encapsulating an integrated circuit optical sensor as in claim 56 wherein the seal material comprises:
 a sealant; and
 a plurality of uniformly sized spacer elements mixed with the sealant.

15 58. A package for encapsulating an integrated circuit optical sensor as in claim 31 further comprising coating the optical sensor with a transparent curable resin to provide environmental protection.

20 59. A method for encapsulating an integrated circuit optical sensor, the package mountable on a support substrate, the sensor having a top surface containing imaging electronics connected to a plurality of sensor bonding pads, the sensor bonding pads operable to provide flip chip bonding points for connections off the sensor, the method comprising:

 forming a base substrate from a nonconductive material, the base substrate having a top surface and a bottom surface, the base substrate having a region on the bottom surface onto which the sensor will be attached;

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depositing a plurality of conducting strips on the base substrate bottom surface, each strip extending from the region onto which the sensor will be attached to an edge of the base substrate bottom surface; and

5 flip chip bonding the sensor top surface to the base substrate bottom surface such that each sensor bonding pad is connected to a corresponding conductive strip.

60. A method for encapsulating an integrated circuit optical sensor as in claim 59 wherein the base substrate is opaque, the method further comprising:

10 forming a hole in the base substrate through which the imaging electronics can receive light; and

bonding a window to the base substrate top surface in a spaced-apart relationship using a seal material, the window large enough to cover the hole, the window operable to admit light onto the imaging electronics.

15 61. A method for encapsulating an integrated circuit optical sensor as in claim 60 wherein the window is one substrate of an electrochromic variable attenuator.

20 62. A method for encapsulating an integrated circuit optical sensor as in claim 60 wherein the window is a first window, the method further comprising:

depositing a first transparent electrode on the first window top surface;

forming a second window from a nonopaque material, the second window having a bottom surface with a second transparent electrode deposited thereon;

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bonding the second window to the first window top surface in a spaced-apart relationship using a seal material, a cavity thereby formed with the first window, the second window, and the seal material bonding the second window to the first window;

5 forming at least one opening in the cavity;
 filling the cavity with an electrochromic medium through the at least one opening;
 sealing the at least one opening; and
 attaching electrical connections to the first transparent electrode
10 and the second transparent electrode.

63. A method for encapsulating an integrated circuit optical sensor as in claim 59 wherein the base substrate is transparent and wherein the base substrate forms one substrate of an electrochromic variable attenuator.

64. A method for encapsulating an integrated circuit optical
15 sensor as in claim 59 wherein the base substrate is transparent, the method further comprising:
 depositing a first transparent electrode on the top surface of the base substrate;
 forming a window from a nonopaque material, the window
20 having a bottom surface with a second transparent electrode deposited thereon;
 bonding the window to the base substrate top surface in a spaced-apart relationship using a seal material, a cavity thereby formed with the base substrate, the window, and the seal material bonding the window to the base substrate;
25 forming at least one opening in the cavity;
 filling the cavity with an electrochromic medium through the at least one opening;

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sealing the at least one opening; and
attaching electrical connections to the first transparent electrode
and the second transparent electrode.

5 65. A method for encapsulating an integrated circuit optical
sensor as in claim 59 further comprising bonding a cover to the base substrate
bottom surface in a spaced-apart relationship using a seal material, the base
substrate, the cover, and the seal material bonding the cover to the base
substrate forming a protective enclosure for the optical sensor.

10 66. A method for encapsulating an integrated circuit optical
sensor as in claim 65 wherein the base substrate, the cover, and the seal
material bonding the cover to the base substrate form a cavity, the method
further comprising filling the cavity with a transparent curable resin.

15 67. A method for encapsulating an integrated circuit optical
sensor as in claim 59 further comprising coating the optical sensor with a
transparent curable resin.

 68. A method for encapsulating an integrated circuit optical
sensor as in claim 59 further comprising placing a clip on the base substrate for
each conducting path, each clip extending from one conducting path at the edge
of the base substrate top surface to the base substrate bottom surface.

20 69. A method for encapsulating an integrated circuit optical
sensor as in claim 59 wherein the base substrate is glass, forming the base
substrate comprises:

 forming a large sheet of glass;

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scoring the glass with vertical and horizontal lines, the spacing between lines defining the size of the base substrate; and breaking the glass along the scored lines.

5 70. A method for encapsulating an integrated circuit optical sensor as in claim 59 wherein depositing a plurality of conductive strips comprises depositing successive layers of chrome, rhodium, and gold.

 71. A method for encapsulating an integrated circuit optical sensor as in claim 59 wherein depositing a plurality of conducting strips on the base substrate top surface comprises:
10 forming a mask on the base substrate top surface having openings over each area on which each conducting strip will be deposited; sputtering a conducting material onto the base substrate top surface; and removing the mask.

15 72. A method for encapsulating an integrated circuit optical sensor as in claim 59 wherein depositing a plurality of conducting strips on the base substrate top surface comprises:
 depositing a conducting material on the base substrate top surface;
20 forming a mask on the deposited conducting material, the mask covering each area on which a conducting strip is desired; etching away the conducting material exposed by the mask; and removing the mask.

25 73. An optical sensor with controlled light attenuation comprising:

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an optical sensor assembly comprising an integrated circuit
optical sensor disposed within a package, the optical sensor comprising imaging
electronics, the package comprising a package window through which light
strikes the imaging electronics; and

5 a variable attenuator bonded to the package in a spaced-apart
relationship by a seal material, the seal material extending around the package
window.

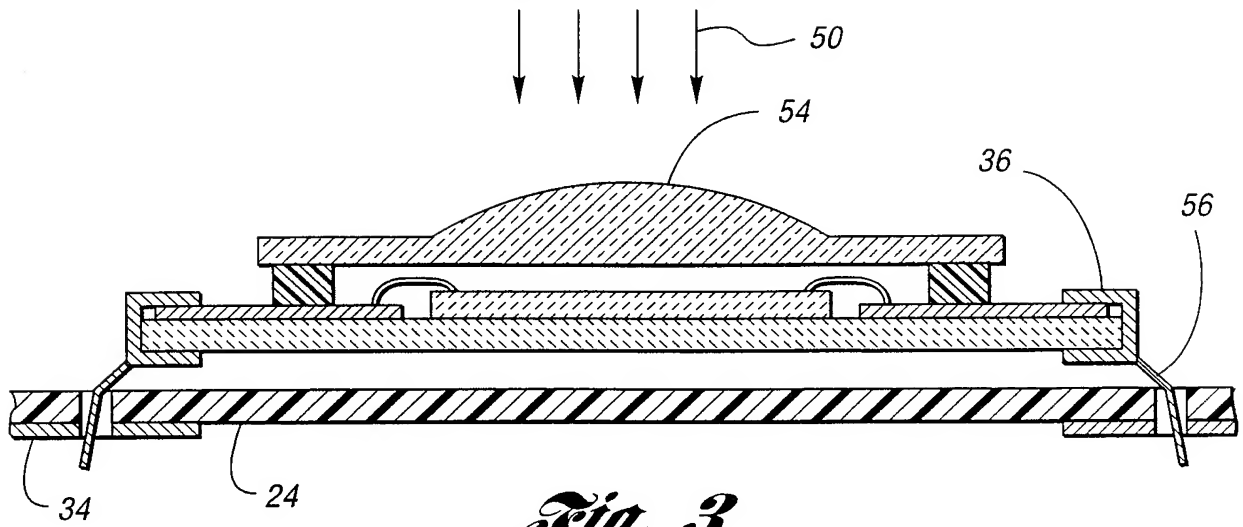
74. An optical sensor as in claim 73 wherein the seal material
comprises:

10 a sealant; and
 a plurality of uniformly sized spacer elements mixed with the
sealant.

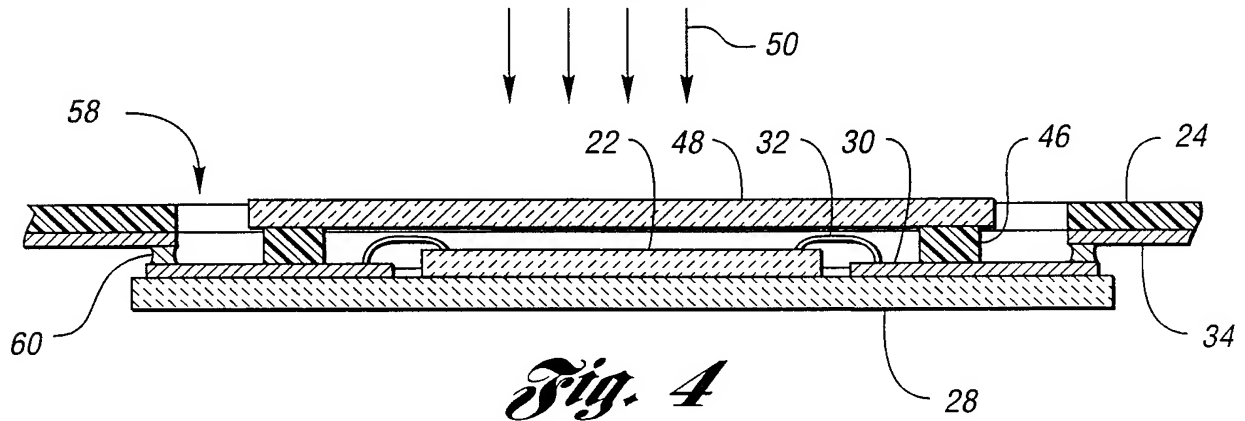
75. An optical sensor as in claim 73 wherein the variable
attenuator is an electrochromic window.

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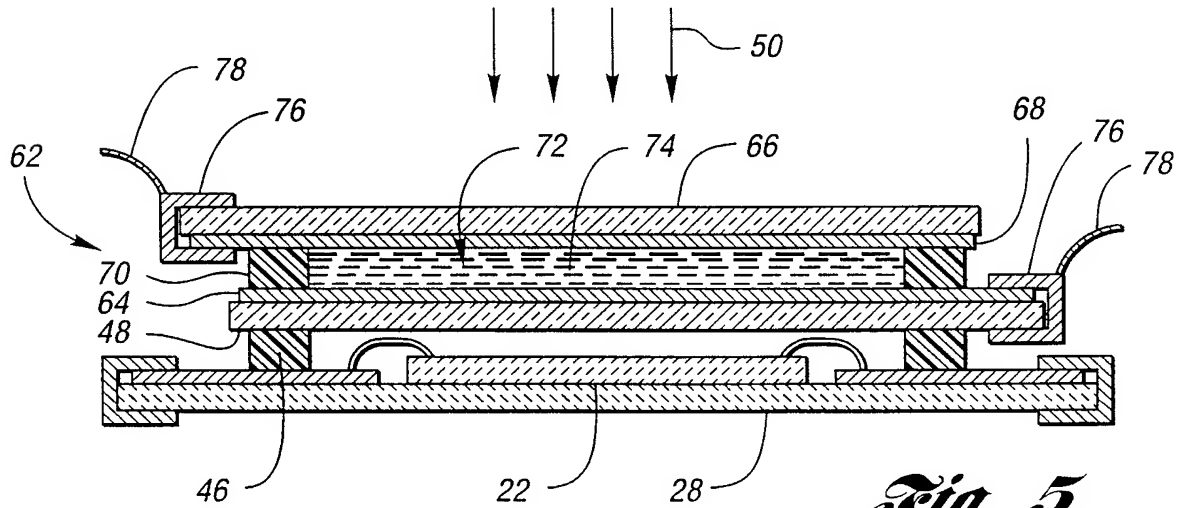
LIGHT DIRECTION

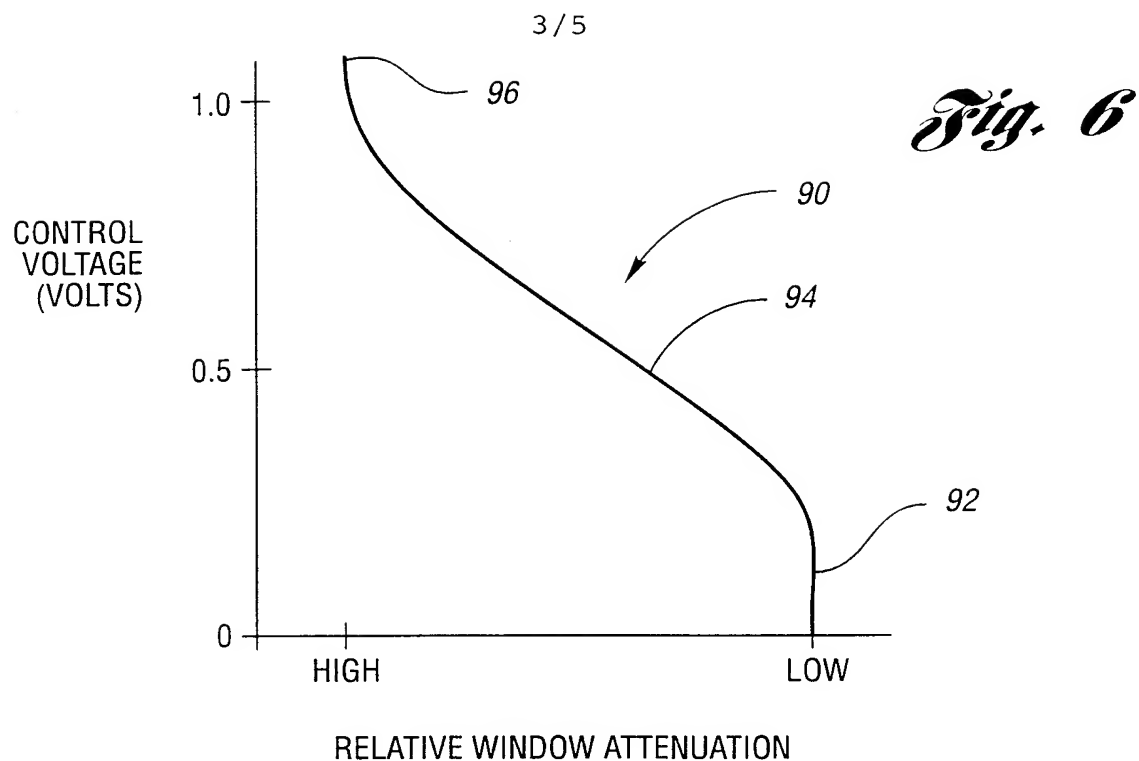
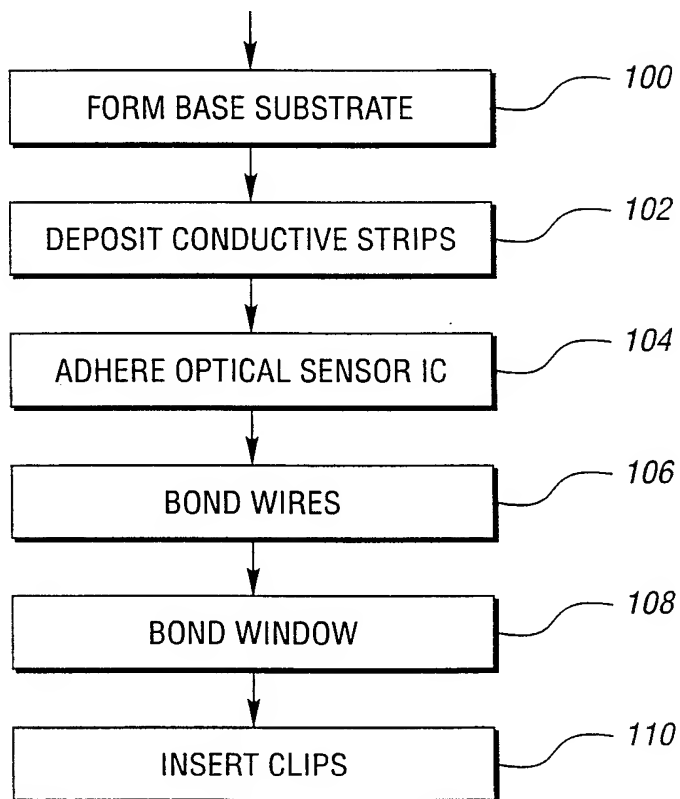


LIGHT DIRECTION



LIGHT DIRECTION



*Fig. 7*

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Fig. 8

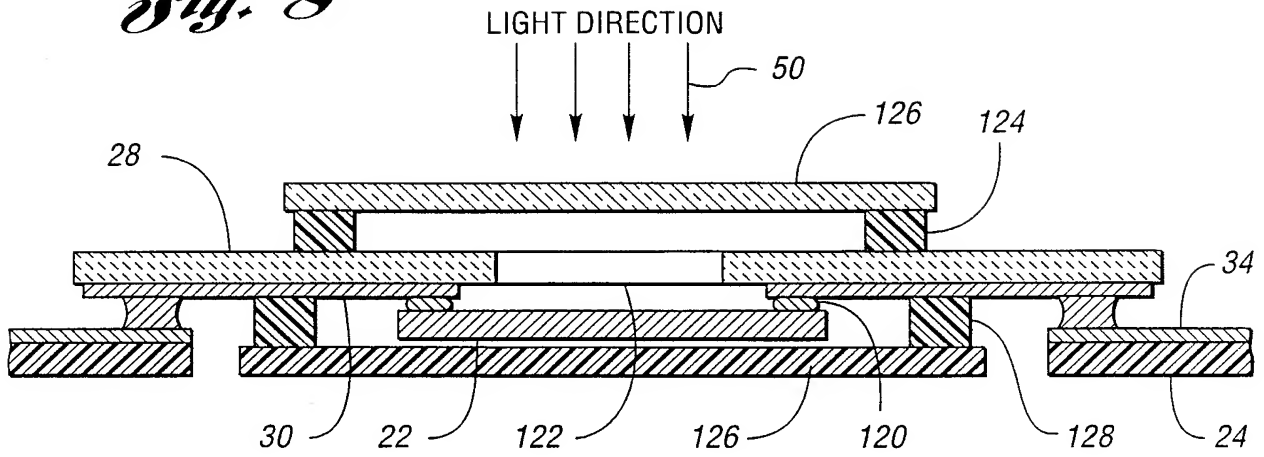


Fig. 9

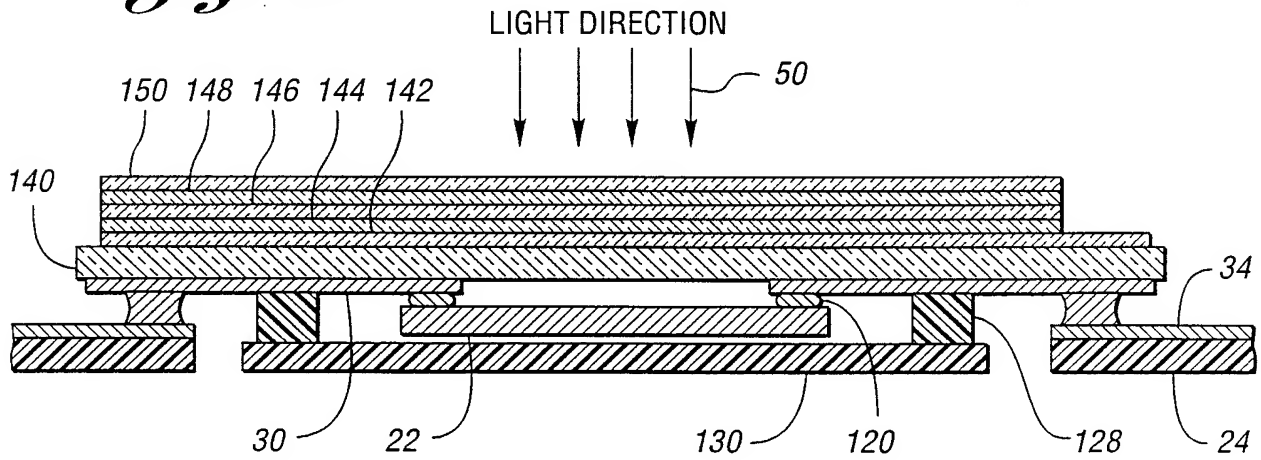
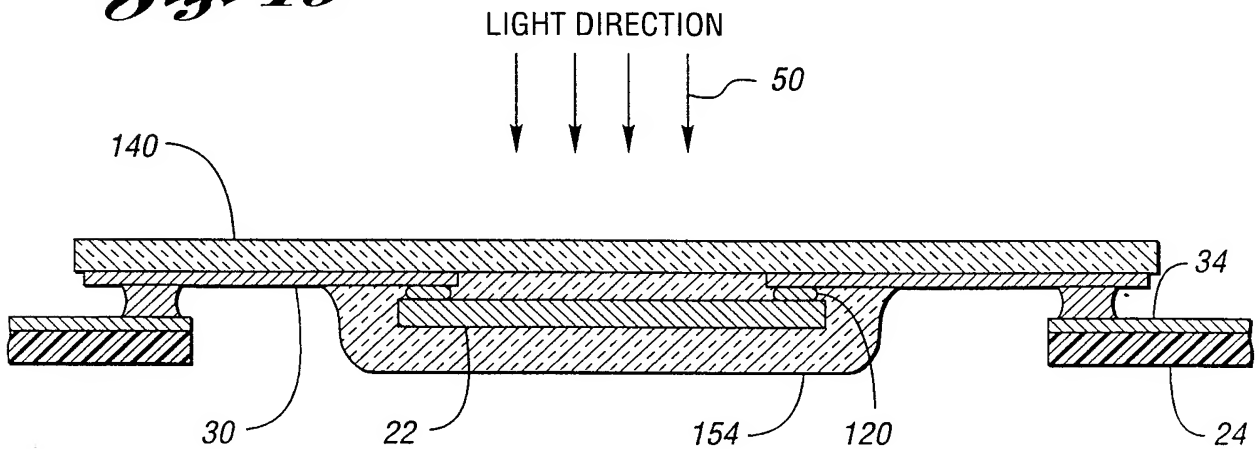
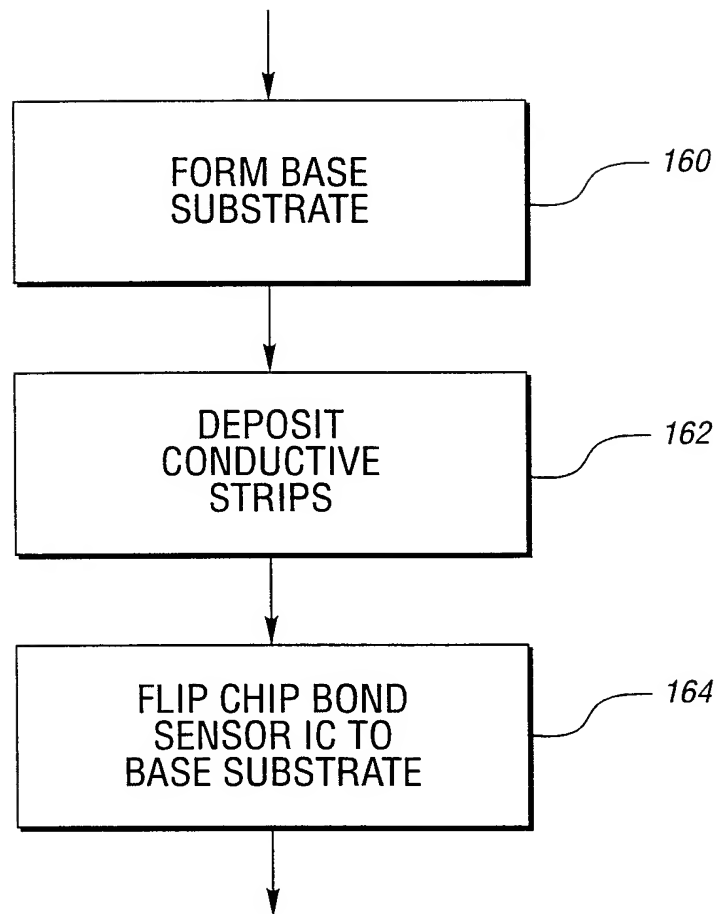


Fig. 10



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*Fig. 11*

INTERNATIONAL SEARCH REPORT

International Application No

PCT/US 99/18612

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H01L31/0203

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H01L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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Y	EP 0 425 776 A (MITSUBISHI ELECTRIC CORP) 8 May 1991 (1991-05-08) column 4, line 1 - line 58 column 7, line 19 - line 43; figures 2,3 ---	1,22
Y	PATENT ABSTRACTS OF JAPAN vol. 012, no. 261 (E-636), 22 July 1988 (1988-07-22) & JP 63 045840 A (SEIKO EPSON CORP), 26 February 1988 (1988-02-26) abstract ---	1,22
A	US 5 051 802 A (PROST ROGER ET AL) 24 September 1991 (1991-09-24) column 3, line 54 - column 4, line 26; claim 7; figures 1,2 ---	1,10,12, 22,29 73
X	---	
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☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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Date of the actual completion of the international search

19 November 1999

Date of mailing of the international search report

29/11/1999

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INTERNATIONAL SEARCH REPORT

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PCT/US 99/18612

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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A	FR 2 640 430 A (CIT ALCATEL) 15 June 1990 (1990-06-15) page 3, line 31 -page 4, line 25; figure 2 -----	31, 42, 51-60

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